

Comments to RD studies at KARA and ESRF

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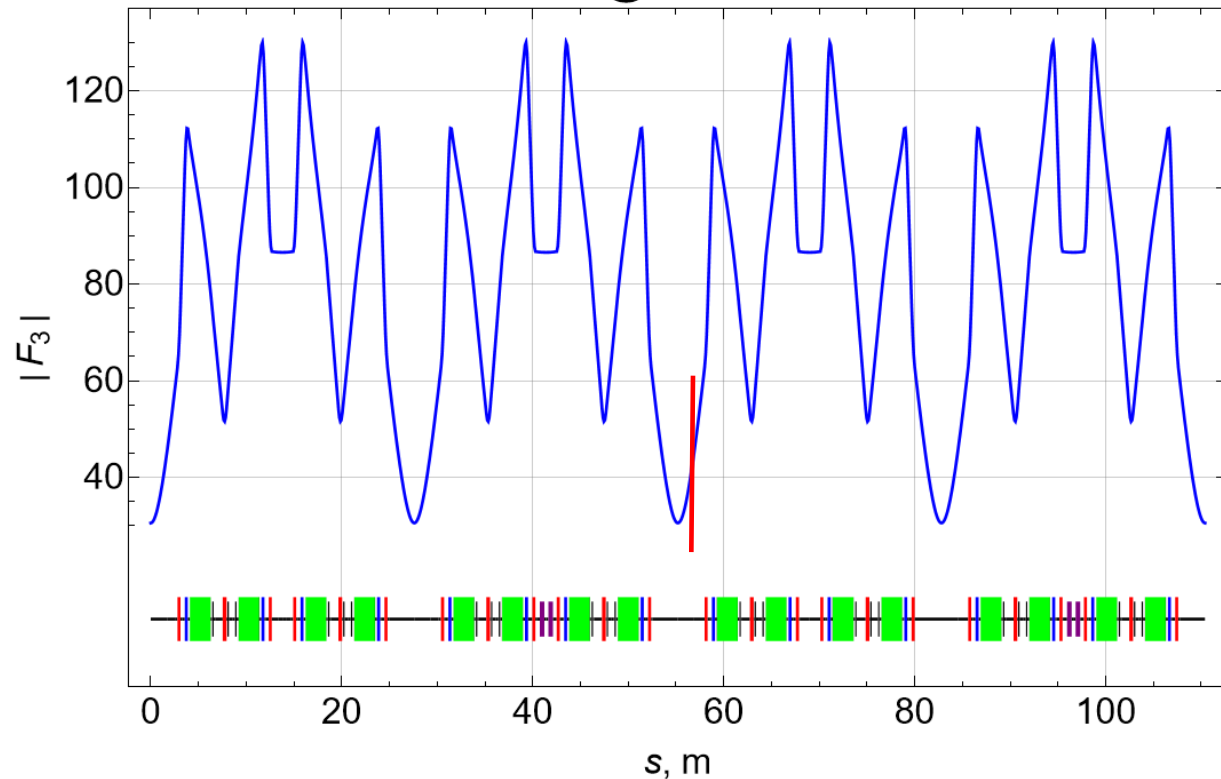
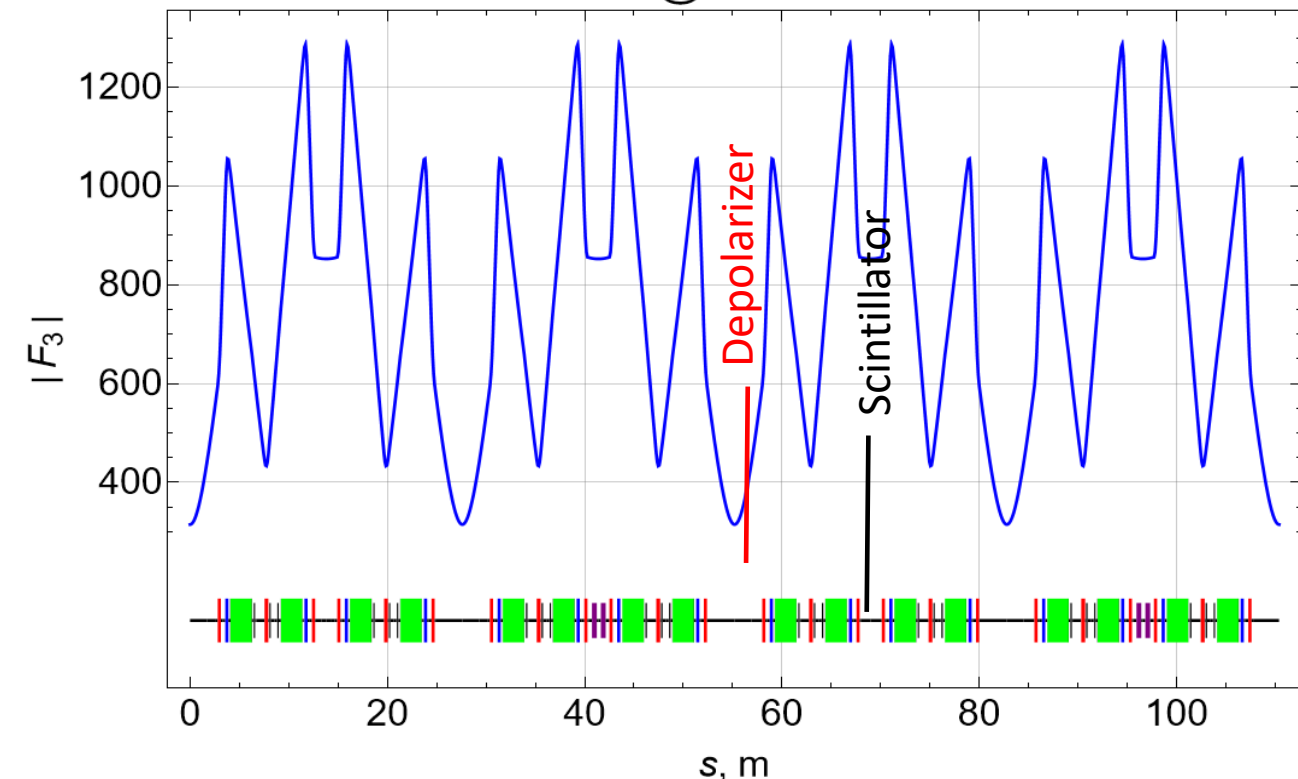
Zoom EPOL meetings, CERN

March 06, 2023

KARA spin-orbit response function F3

KARA @ $E = 2.3$ GeV

KARA @ $E = 2.5$ GeV



Depolarizer angle for $P=160$ W, $Z=8$ kOhm:

$$\Delta\theta = \frac{e\sqrt{2PZ}}{E} = \begin{cases} 7.0 \cdot 10^{-7} & E = 2.3 \text{ GeV} \\ 6.4 \cdot 10^{-7} & E = 2.5 \text{ GeV} \end{cases}$$

Depolarizer harmonic strength:

$$w = \frac{\Delta\theta}{2\pi} |F3| = \begin{cases} 4.4 \cdot 10^{-5} & E = 2.3 \text{ GeV} \\ 4.0 \cdot 10^{-6} & E = 2.5 \text{ GeV} \end{cases}$$

Strong intrinsic resonance at $E = 2.3155$ GeV: $\nu_0 = 5.2543$, $\nu_y = 2.7457$, $\nu_0 + \nu_y = 8$, 8 KARA superperiods!

Its RMS harmonic value: $w_{k=8} = 1.68 \cdot 10^{-4}$, for betatron coupling $\varepsilon_y/\varepsilon_x = 0.01$.

KARA RD at 2.5 GeV

Beam parameters at 2.5 GeV: $\sigma_E = 0.001$, $\nu_s = .01$, $\nu_0 = 5.674$, $B = \nu_0 \sigma_E / \nu_s = 0.567$,
 $J_0(B) = 0.92$ - relatively small reduction of the depolarizer strength!

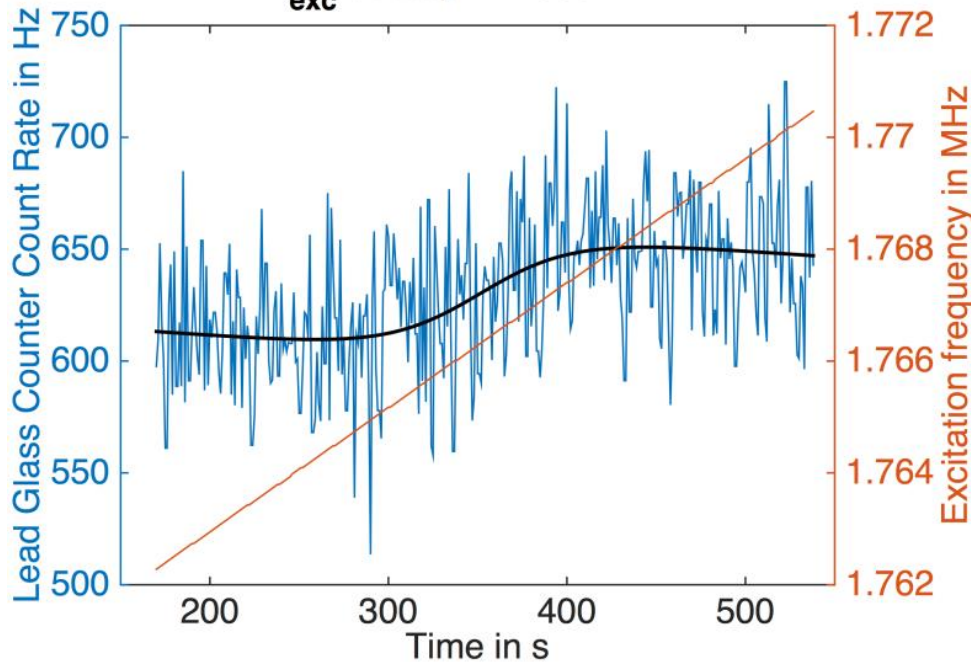
Sweep speed: $d\varepsilon = \dot{f}/f_0^2 = 3 \cdot 10^{-12}$ per turn ($\dot{f}=22.2$ Hz/s, $f_0 = 2.715$ MHz)

B. Härer, E. Blomley – Possible beam tests at KARA:

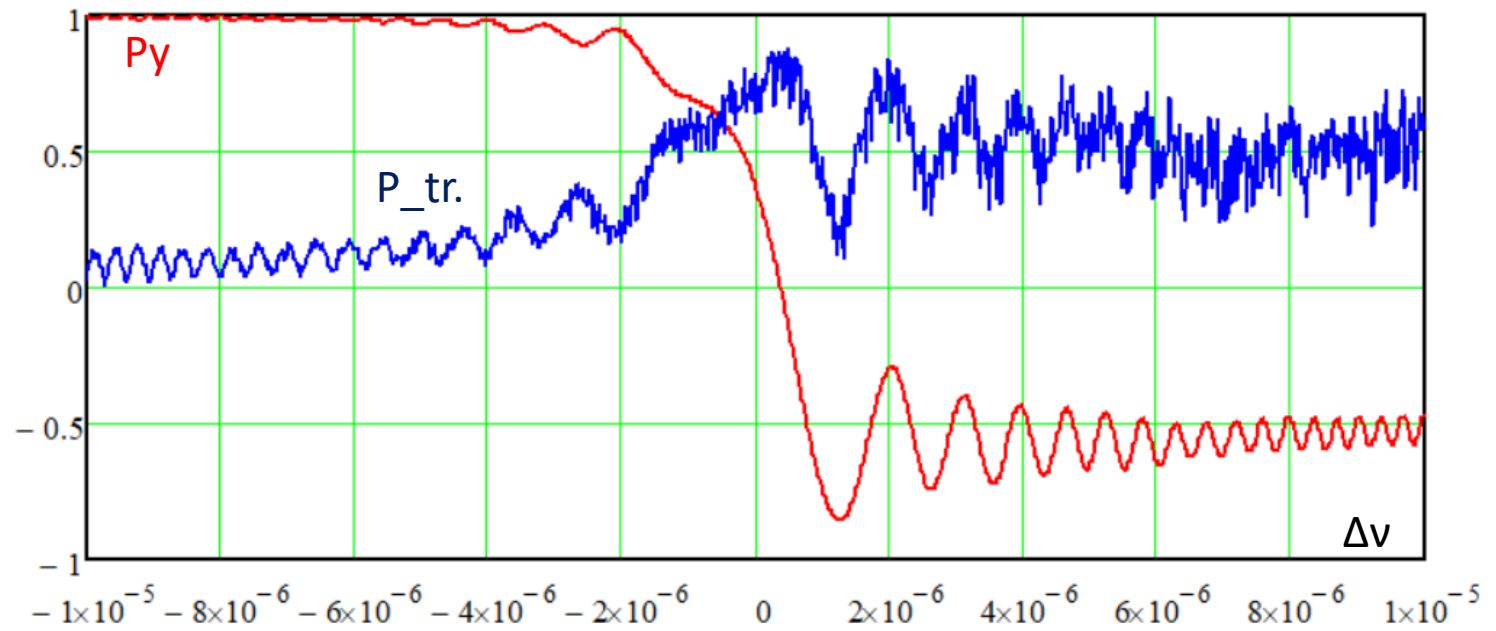
Simulation with the reduced 4 times depolarizer (P=10 W) $w=1e-6$:

Range: 170:538 s, E: 2489.8442 MeV
 f_{exc} at step: 1.7663 MHz

KARA 2.484 GeV, $\nu=5.636$, $\nu_s=.01$, $w=1e-6$, $d\nu=3e-12$, $\sigma=1e-3$



$-.0015$ $\leftarrow \Delta\nu$ $\rightarrow .0015$



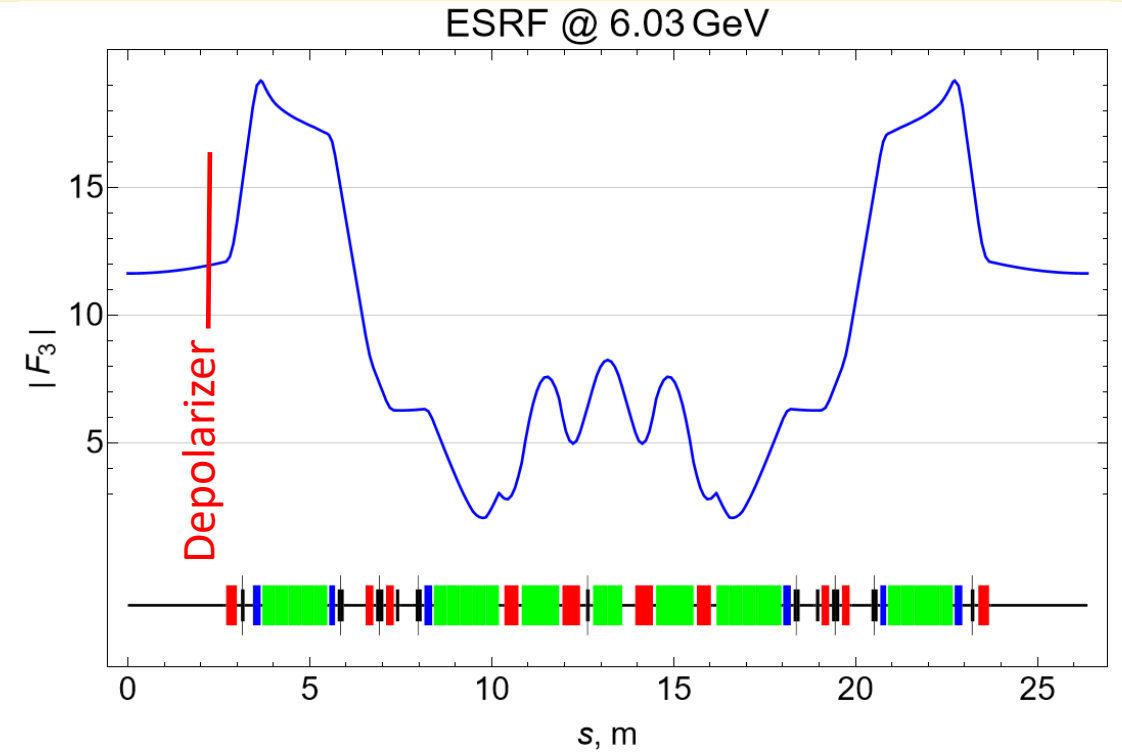
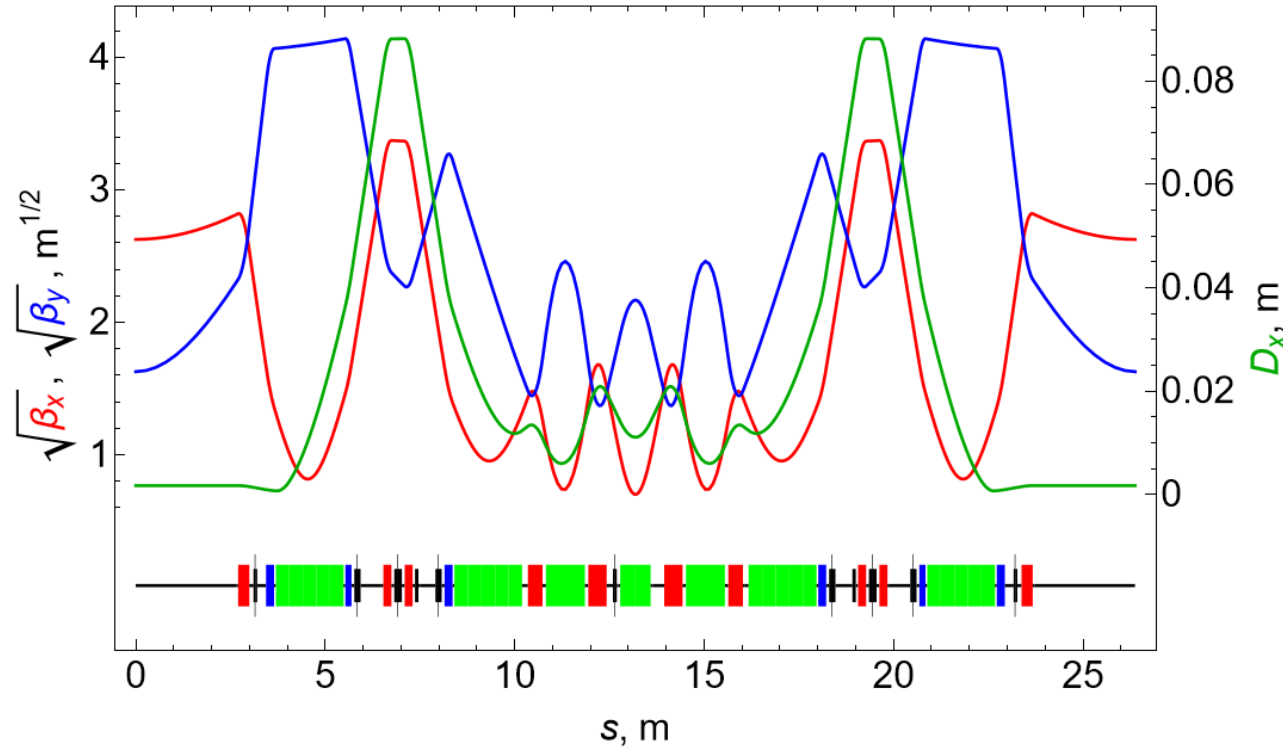
$-.00001$ $\leftarrow \Delta\nu$ $\rightarrow .00001$

Polarization became flipped!

Comments and suggestions for experiments at KARA:

- KARA is a normal ring with high enough synchrotron tune $\nu_s = .01$ and low RMS value of the modulation index $B = \nu_0 \sigma_E / \nu_s = 0.567$, $J_0(B) = 0.92$.
- No any problems with RD!
- Our idealized simulation show a potential to further squeeze the RD uncertainty in the resonance spin tune down to $\Delta\nu=1e-6$ or even better.
- We do not include noise from the power supply and from a RF station. Then depolarization could become not as sharp, as in our simulation.
- We recommend to work with the reduced value of the depolarizer's harmonic w , especially at 2.3 GeV, where F3 is 10 times higher compared with its value at 2.5 GeV. With strong depolarizer a beam will become not depolarized but spin flipped! There is some optimal value of w , when polarization vanishes completely after crossing a resonance - jump in Touschek counting rate is sensitive to $\Delta\langle P_y^2 \rangle$, not to $\Delta\langle P_y \rangle$! It is better to fully depolarize a beam!

ESRF lattice functions and beam parameters



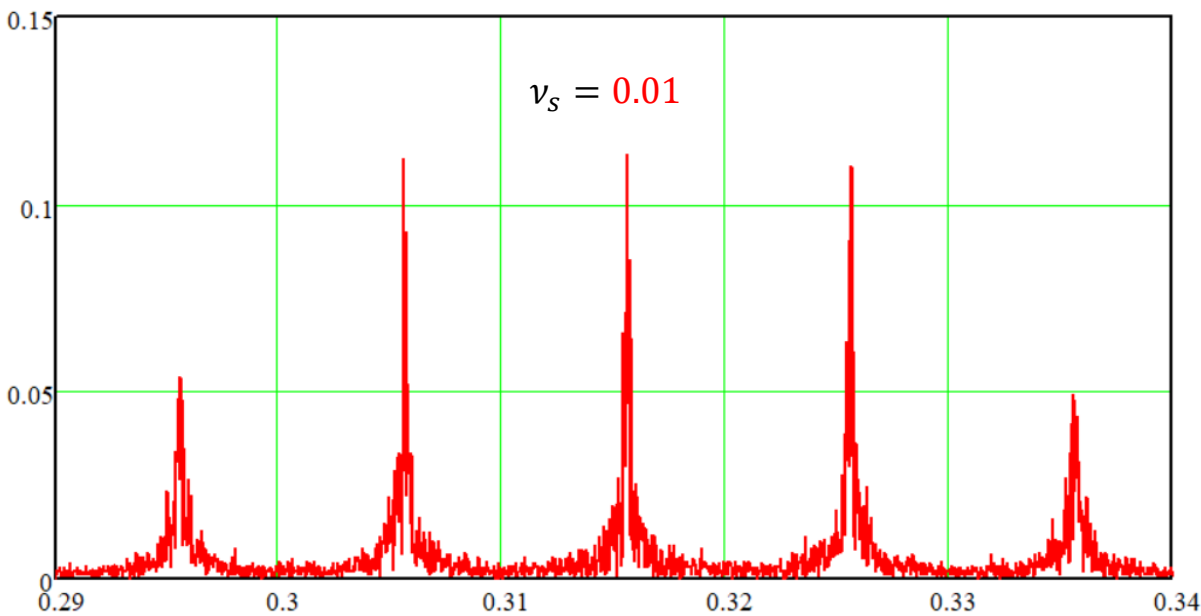
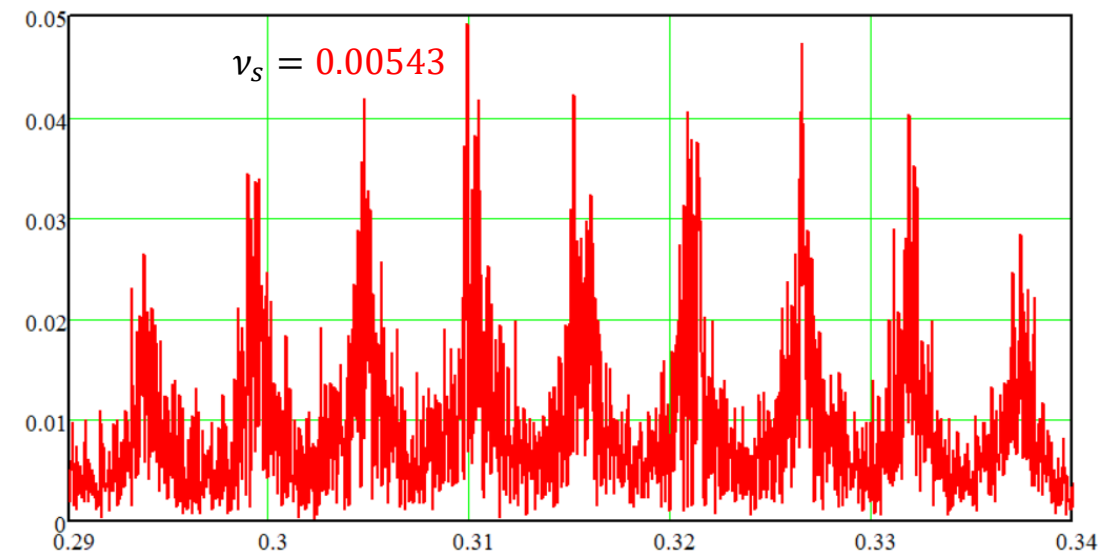
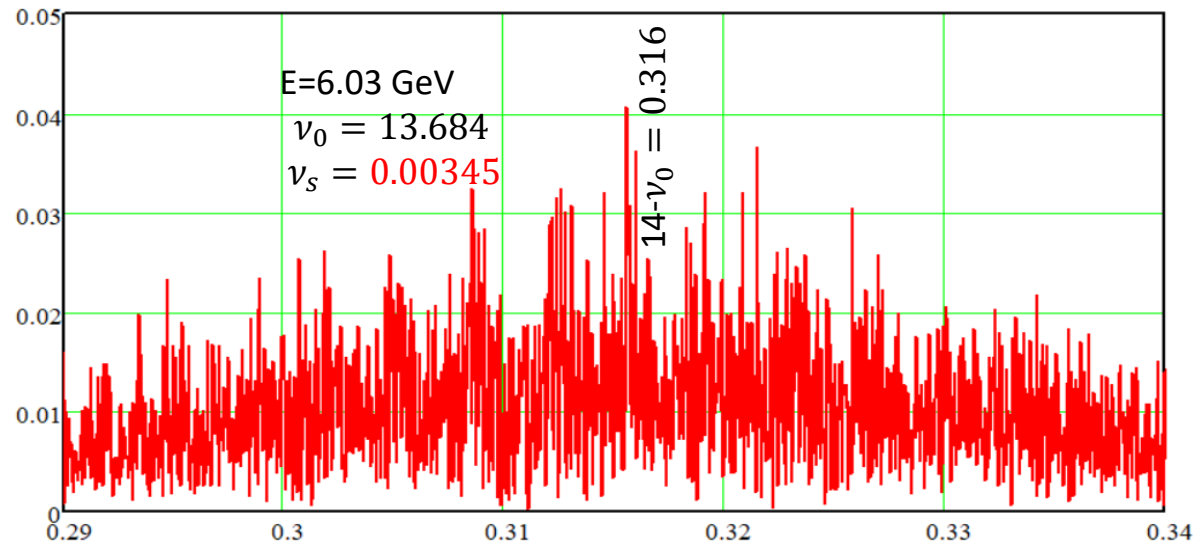
Beam and lattice parameters provided by Simone Liuzzo, Friederike Ewald:

ESRF-EBS at 6.03 GeV: $\sigma_E = 0.001$, $\nu_s = 0.00345$, $\nu_0 = 13.684$, $B = \nu_0 \sigma_E / \nu_s = 4.01$,

$J_0(B) = -0.4$ - the depolarizer strength becomes different for different synchrotron amplitudes! May even change a sign!

Sweep speed: $d\varepsilon = \dot{f}/f_0^2 = 4 \cdot 10^{-10}$ per turn ($\dot{f} = 50$ Hz/s, $f_0 = 0.3552$ MHz)

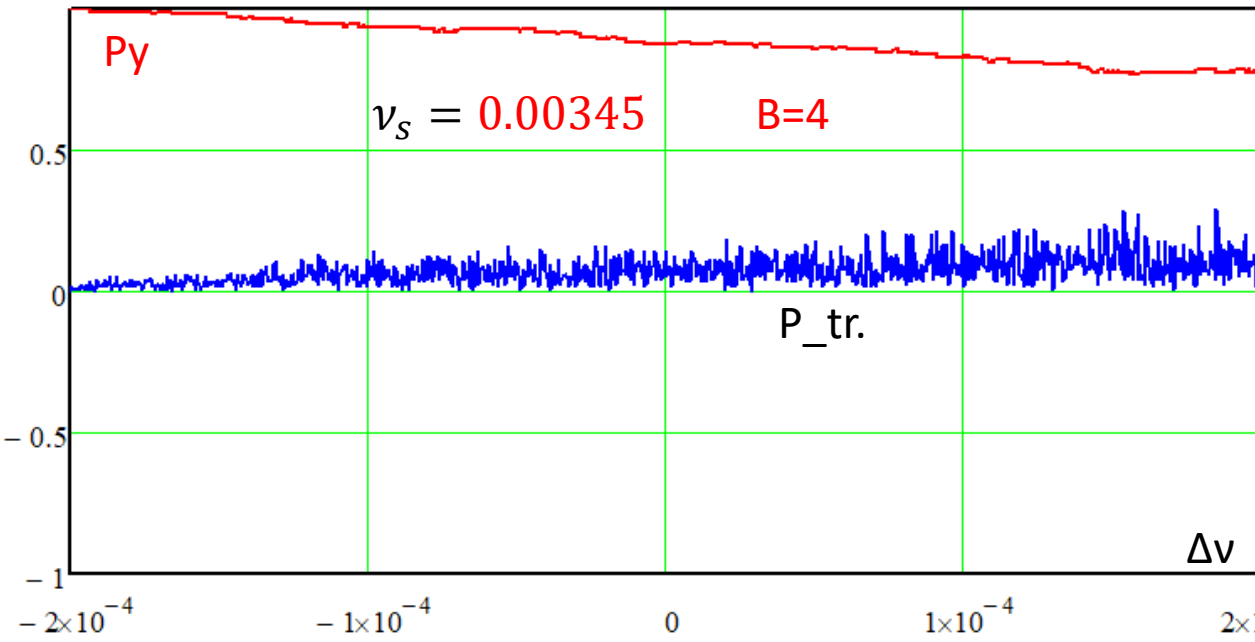
ESRF-EBS free spin precession spectrum in 32768 turns



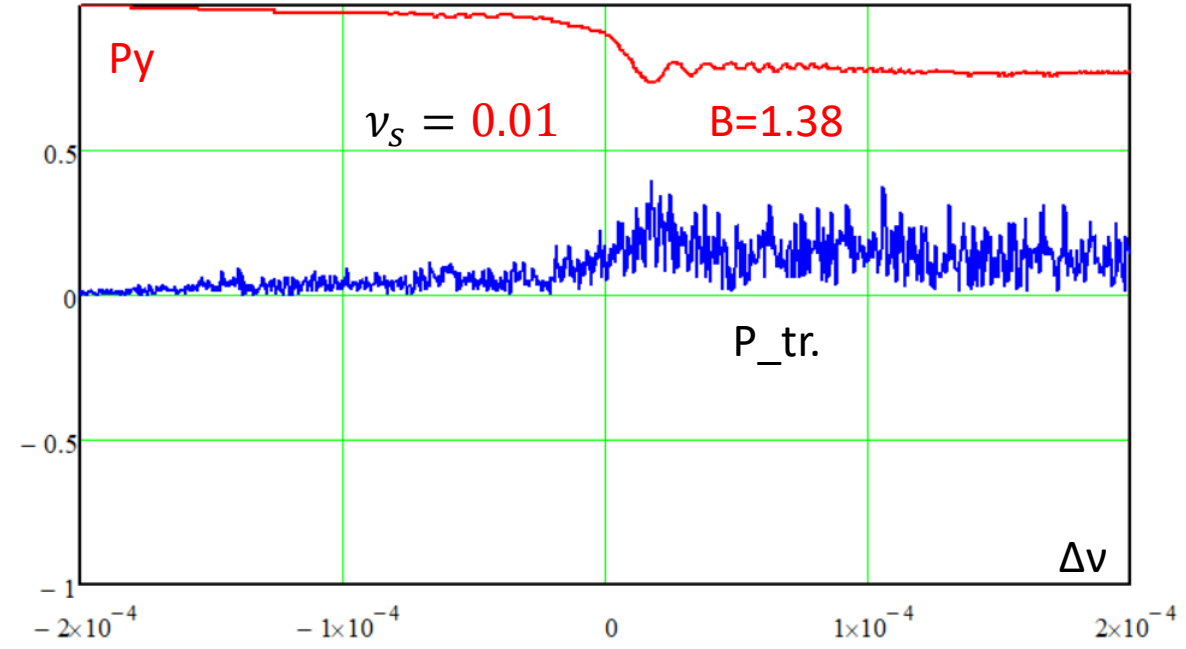
These 3 plots illustrate how the synchrotron side bands become fully overlapped at a nominal synchrotron tune $\nu_s = 0.00345$, while at 2-3 times higher tune the spectrum lines become visible.

Simulation of RD for ESRF-EBS beam parameters

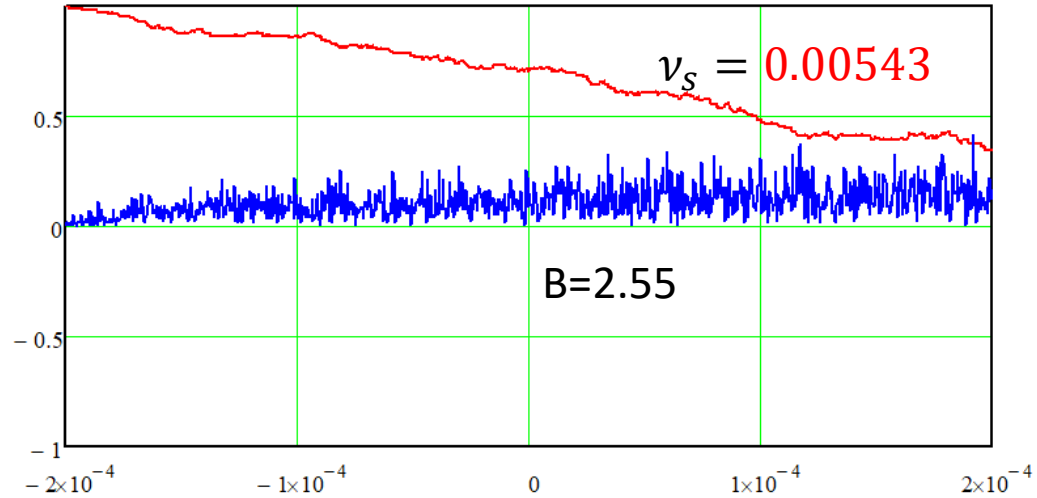
ES 6.03 GeV, $\nu=13.69$, $\nu_s=.0035$, $w=2e-5$, $d\nu=4e-10$, $\sigma=1e-3$



ES 6.03 GeV, $\nu=13.69$, $\nu_s=0.01$, $w=5e-6$, $d\nu=4e-10$, $\sigma=1e-3$



ES 6.03 GeV, $\nu=13.69$, $\nu_s=.0055$, $w=2e-5$, $d\nu=4e-10$, $\sigma=1e-3$



These plots illustrate that only with the enhanced synchrotron tune $\nu_s = 0.01$ the Resonant Depolarization is possible.

Lessons learned for FCC-ee from these studies

- ESRF team had experimentally demonstrated that RD is almost impossible in a storage ring with a large synchrotron modulation index B . It should be kept less than $B < 1.5$. Spin precession spectrum becomes flat in case of large B -index.
- Situation at W production threshold in FCC-ee looks very similar to ESRF_EBS case. With such low the synchrotron tune as $\nu_s = 0.05$ the synchrotron modulation index is too large $B = 2.45$. And only with the increased $\nu_s = 0.08$ the situation becomes somewhat better: $B = 1.53$.
- We should very seriously consider that situation and take significant efforts to find possible ways to increase the synchrotron tune at W energy range up to $\nu_s = 0.08-0.09$.